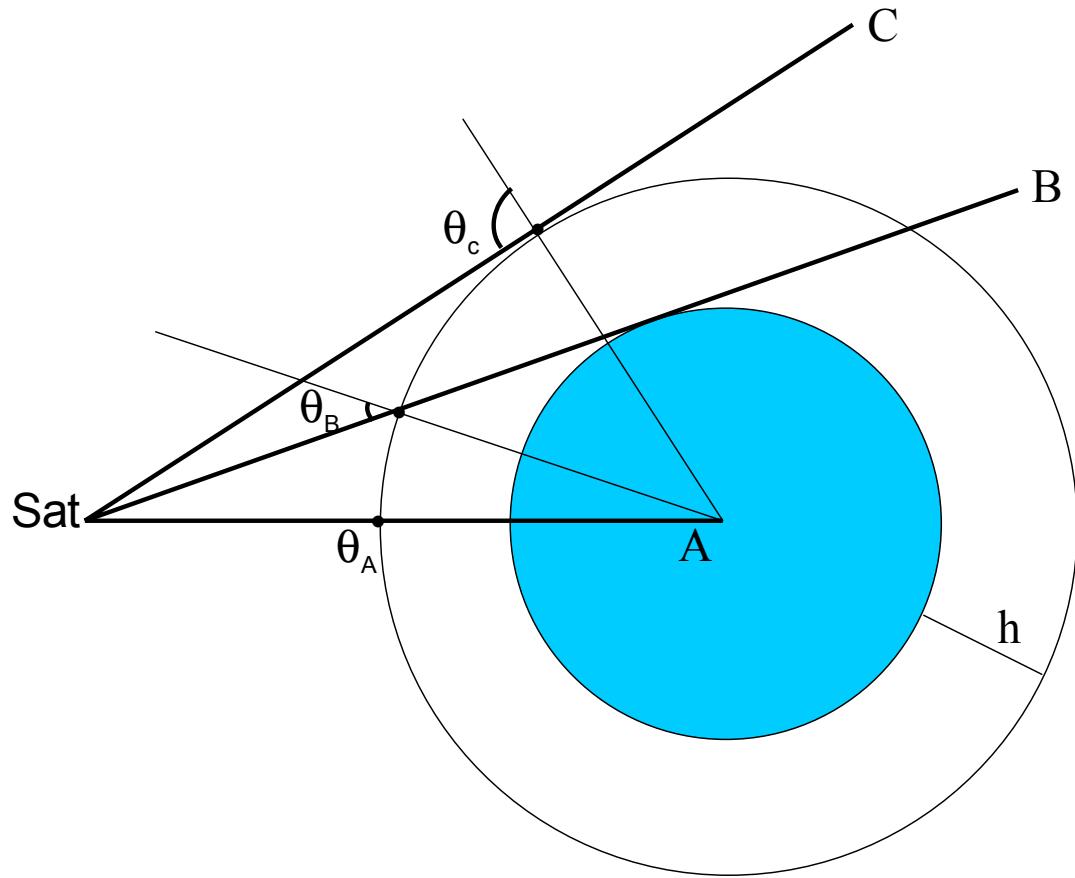


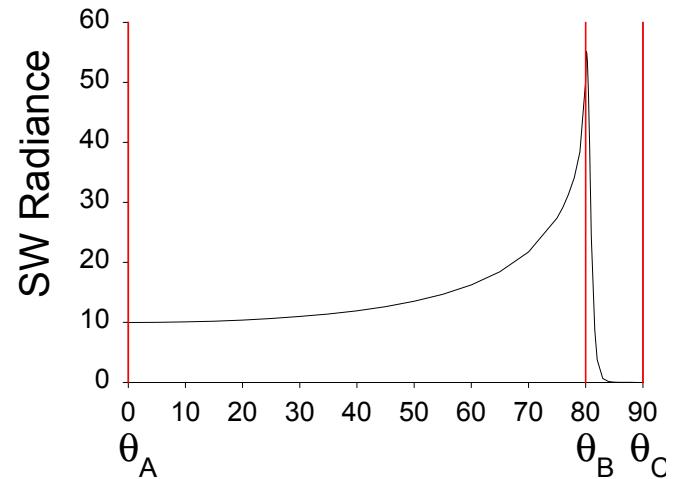
CERES TOA Radiative Flux Reference Level

SW & LW Radiances vs θ

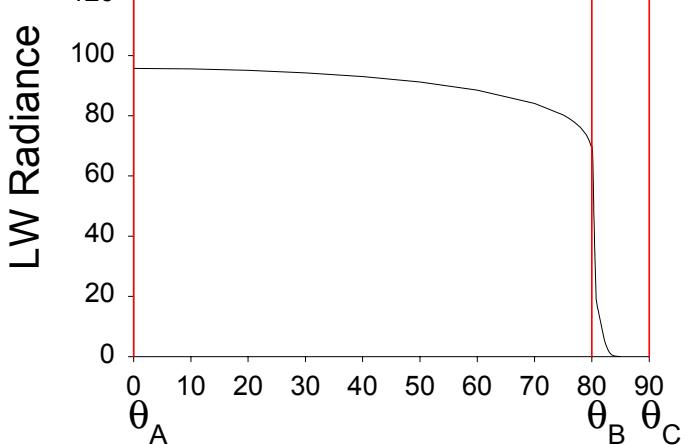
(Spherical Earth Geometry; MODTRAN; Rayleigh Atmosphere)



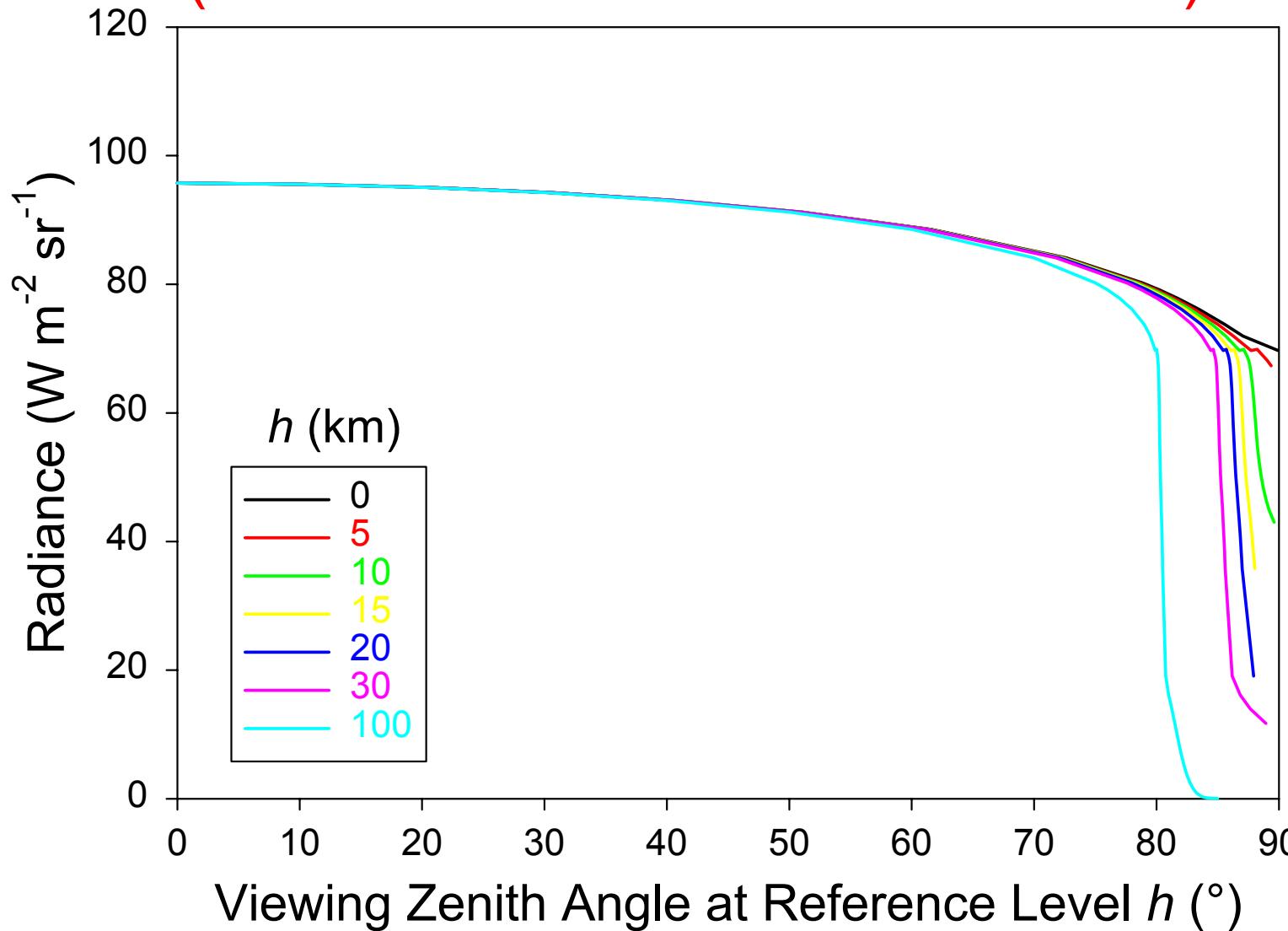
SW Radiance($h=100$ km)



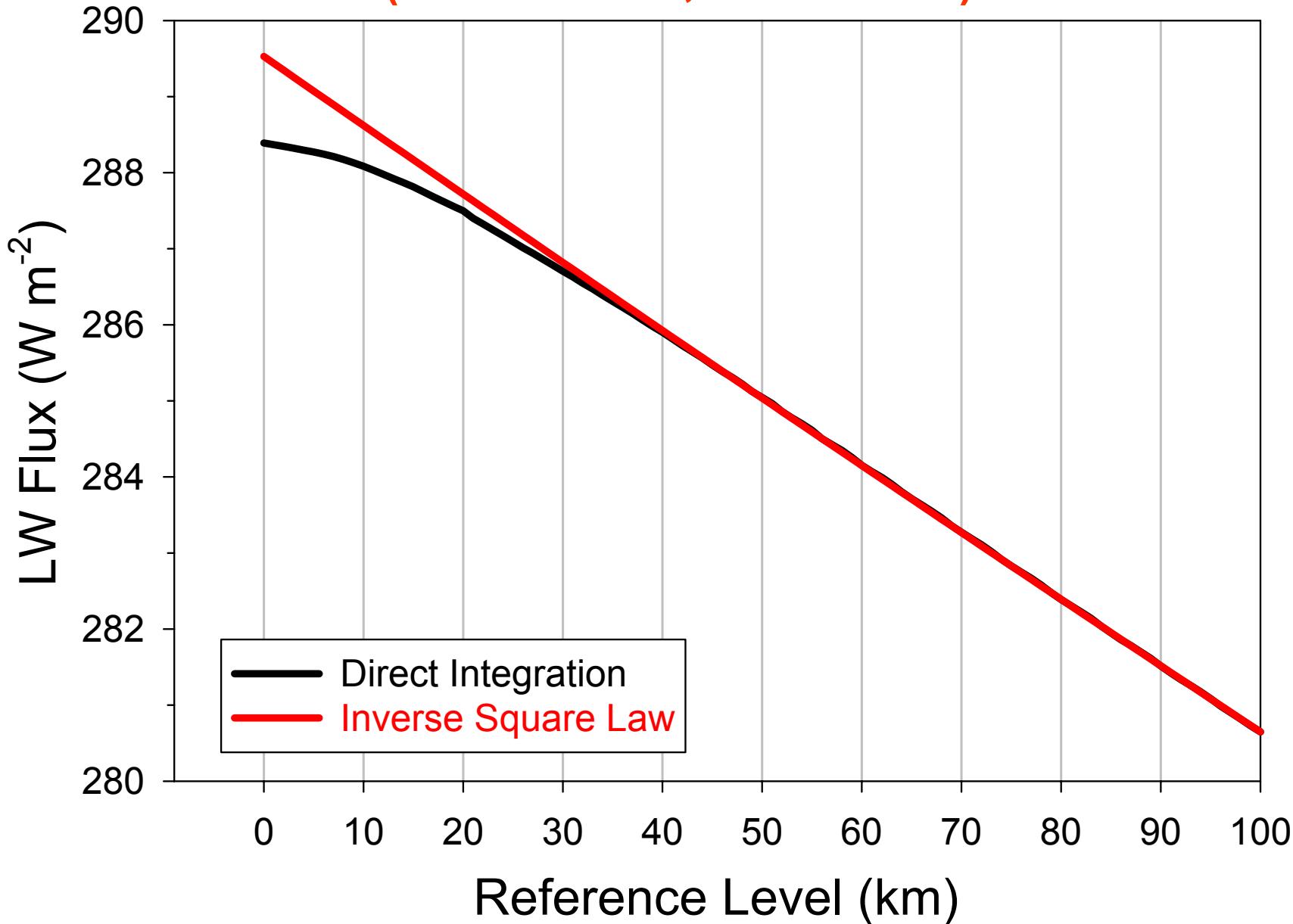
LW Radiance($h=100$ km)



Clear Ocean LW Radiance vs Viewing Zenith Angle (As Function of Reference Level h)

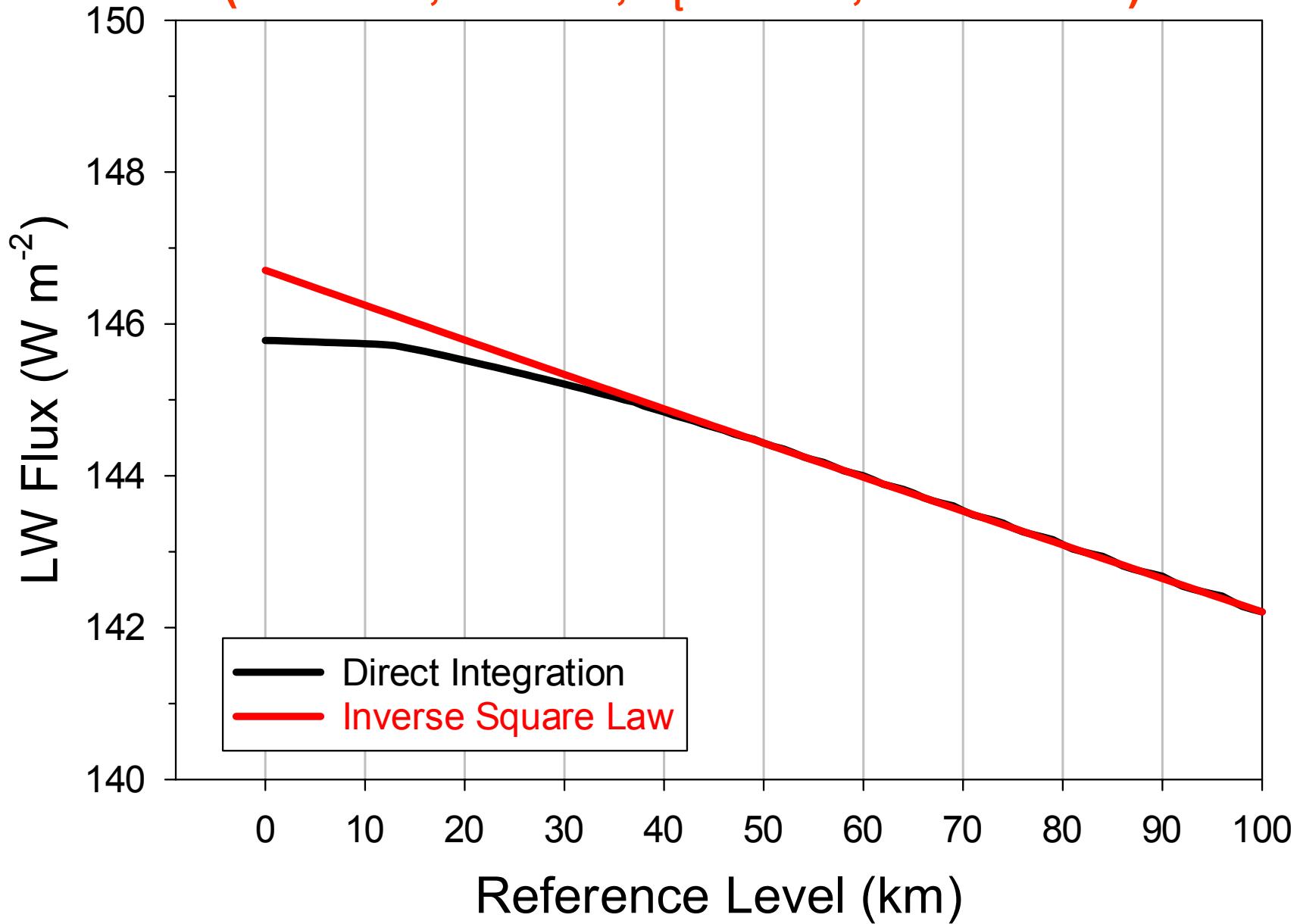


LW Flux vs Reference Level (Clear Ocean; MODTRAN)

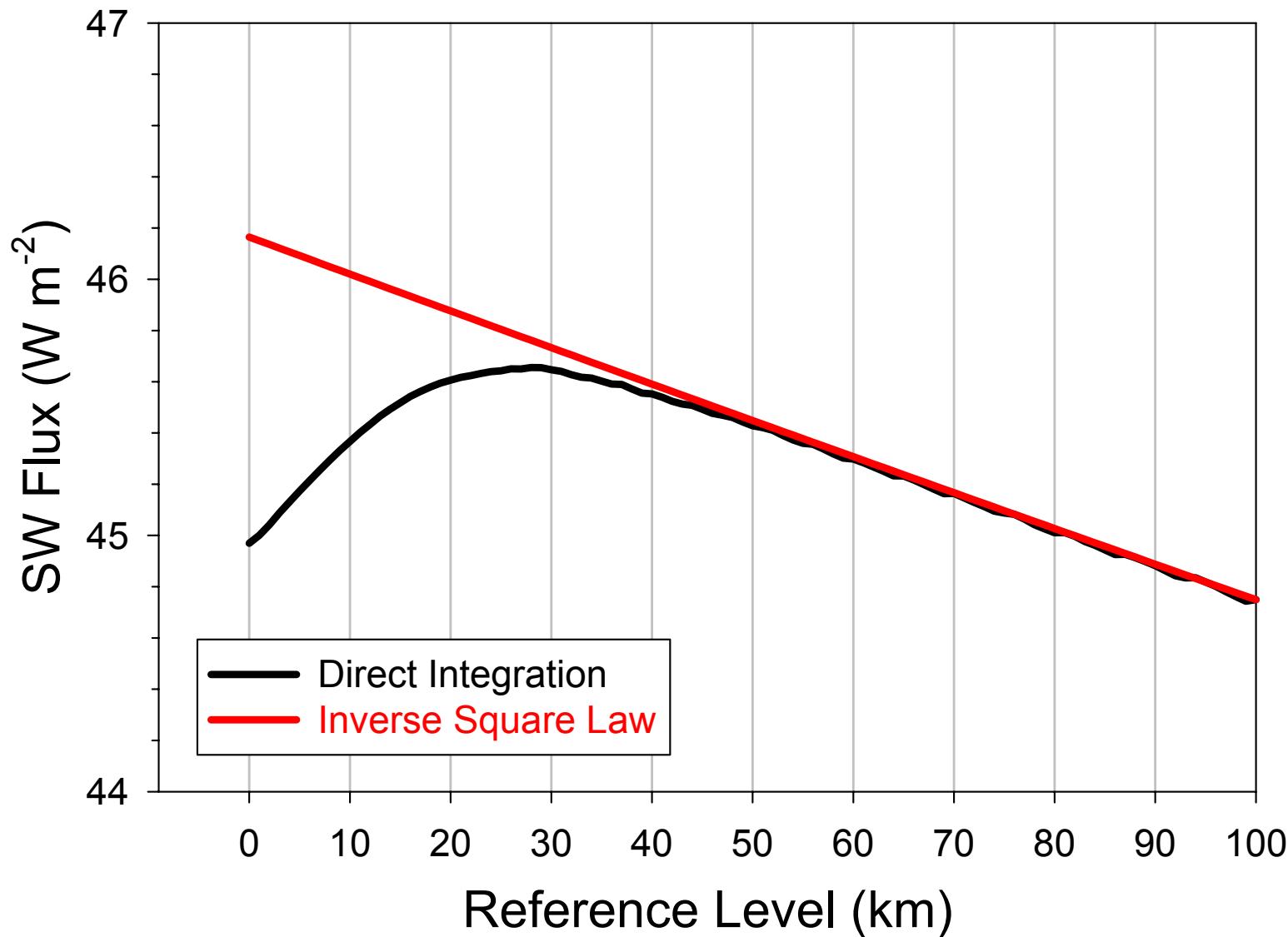


LW Flux vs Reference Level

(Thick Ci; $\tau=1000$; $Z_t=11$ km; MODTRAN)

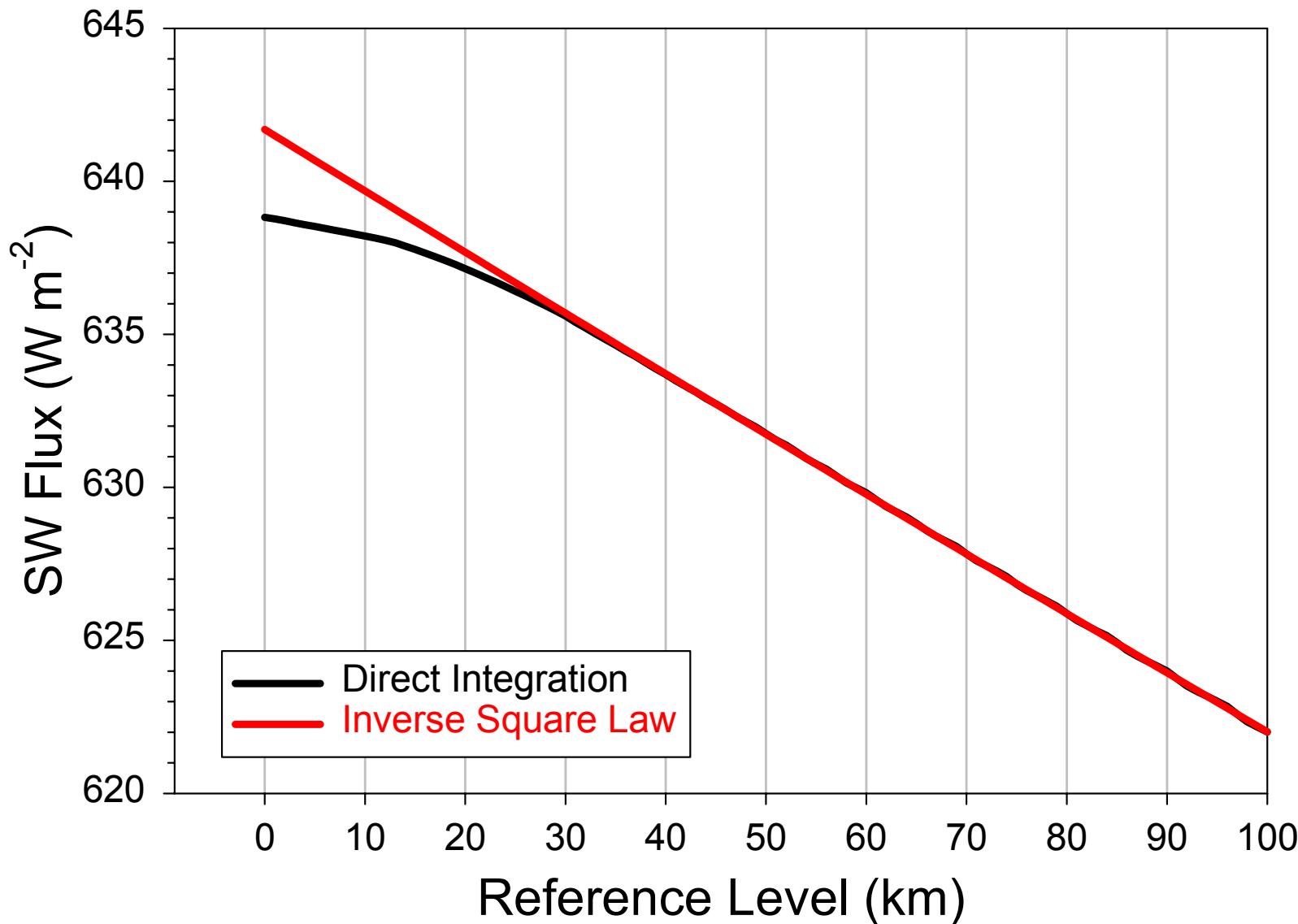


SW Flux vs Reference Level (Rayleigh Atm; $\theta_o=45$; MODTRAN)

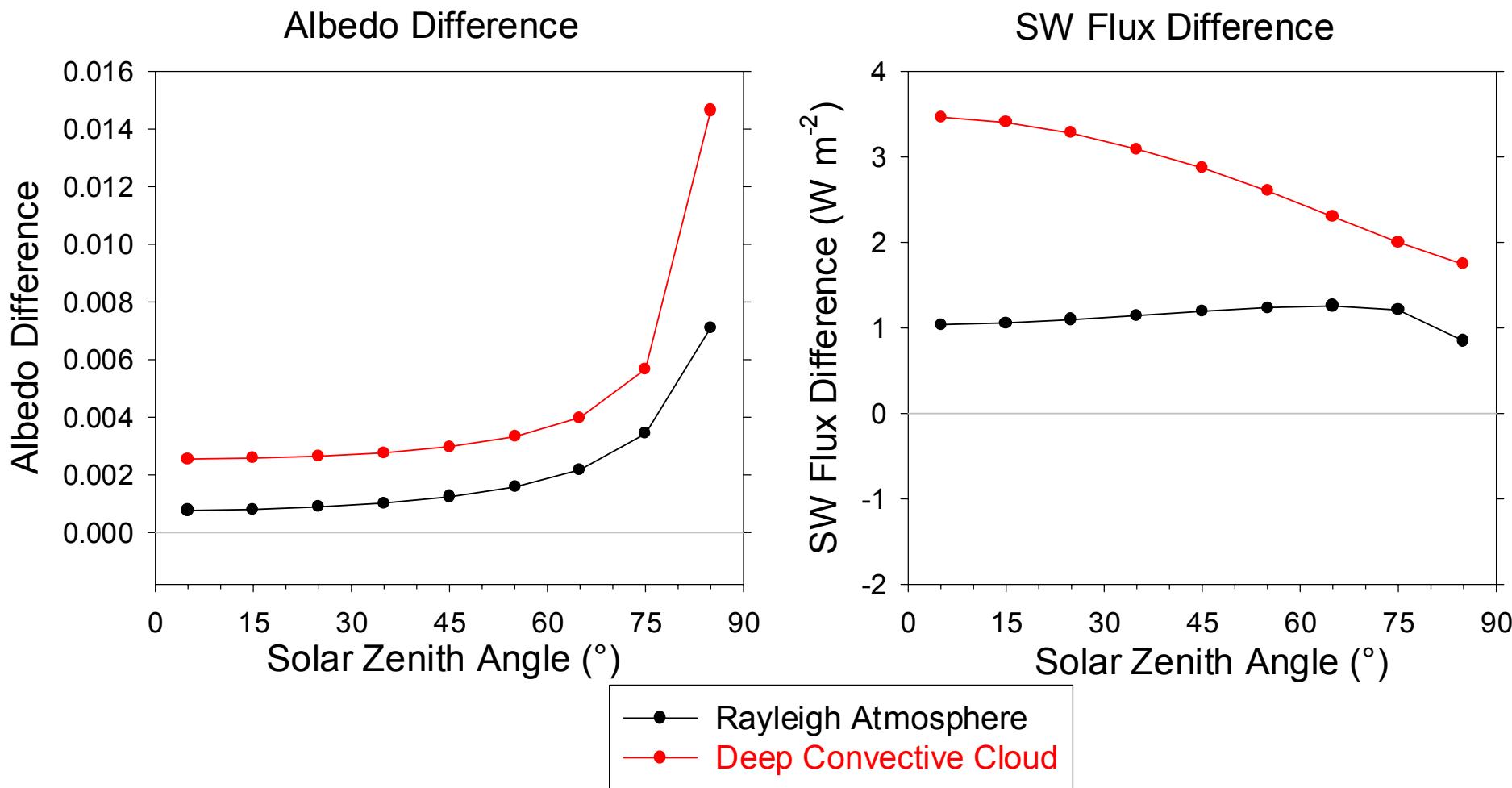


SW Flux vs Reference Level

(Thick Ci; $\tau=1000$; $Z_t=11$ km; $\theta_o=45$; MODTRAN)



Albedo & SW Flux Contribution From Off-Earth Views (MODTRAN; Surface Reference Level)



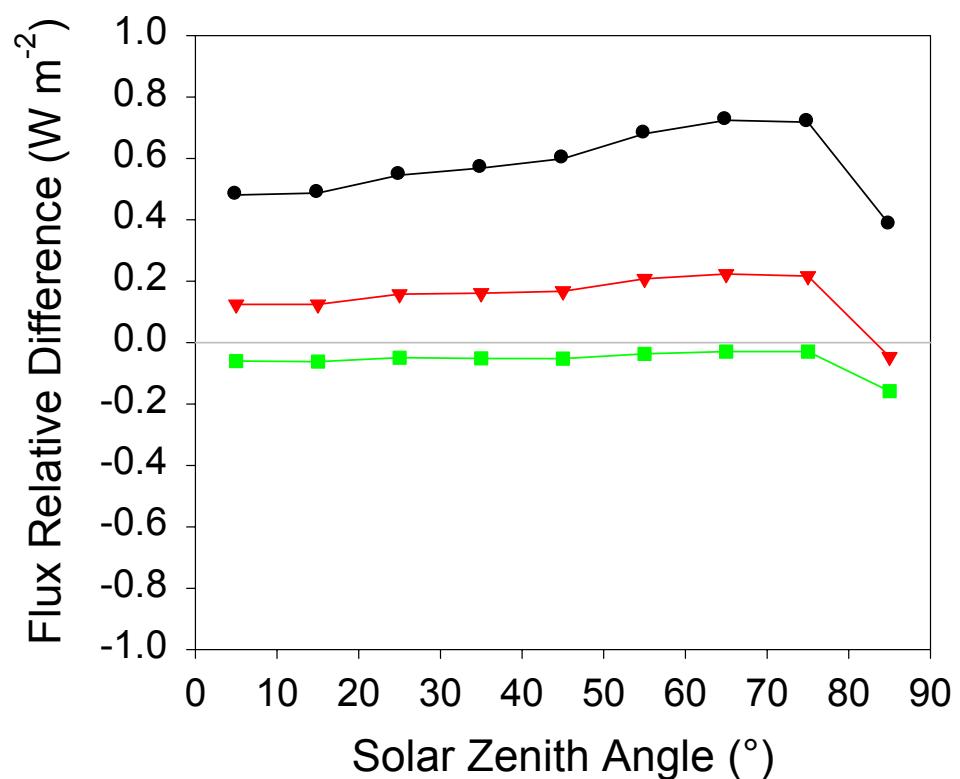
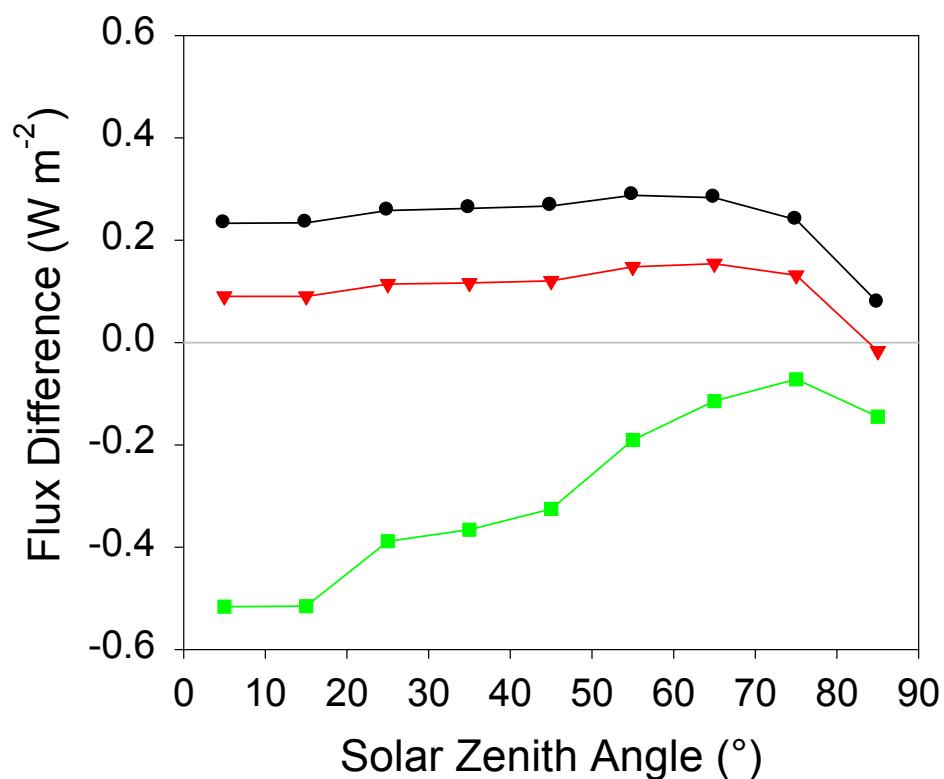
Edition2B ADMs

- Evaluate ADM TOA flux by direct integration at 100-km reference level. Use MODTRAN radiances to fill-in radiances at off-earth views.
- Define ADMs at the surface reference level via inverse square law:

$$R_j^{SW}(\theta_{oi}, \theta_k, \phi_l; h_{sfc}) = \frac{\pi \bar{I}_j^{SW}(\theta_{oi}, \theta_k, \phi_l; h_{sfc})}{F_j^{SW}(\theta_{oi}; h_{100})} \left(\frac{r_e}{r_e + h_{100}} \right)^2$$

$$R_j^{LW}(\theta_k; h_{sfc}) = \frac{\pi \bar{I}_j^{LW}(\theta_k; h_{sfc})}{F_j^{LW}(h_{100})} \left(\frac{r_e}{r_e + h_{100}} \right)^2$$

TOA SW Flux Error by Using MODTRAN to Fill-In Off-Earth Views (Compared with ES8)



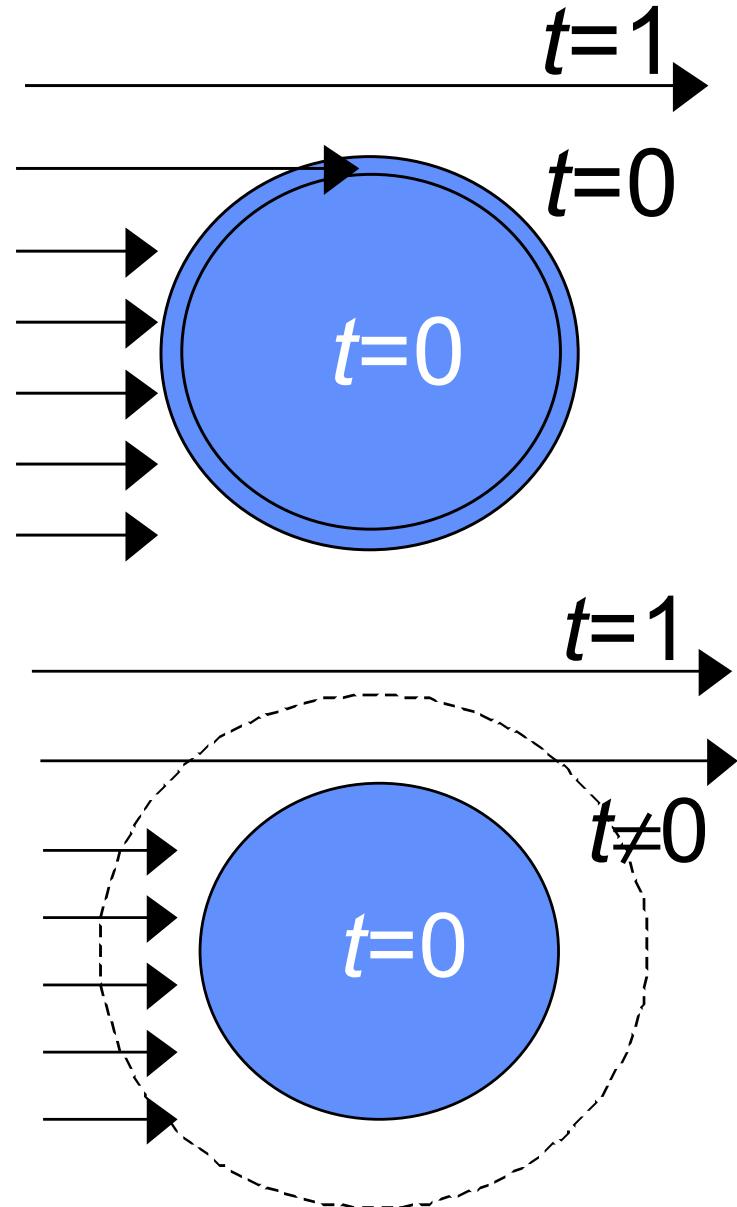
—●— Clear
—▼— Thin Cirrus
—■— Thick Cloud

TOA Flux Reference Level

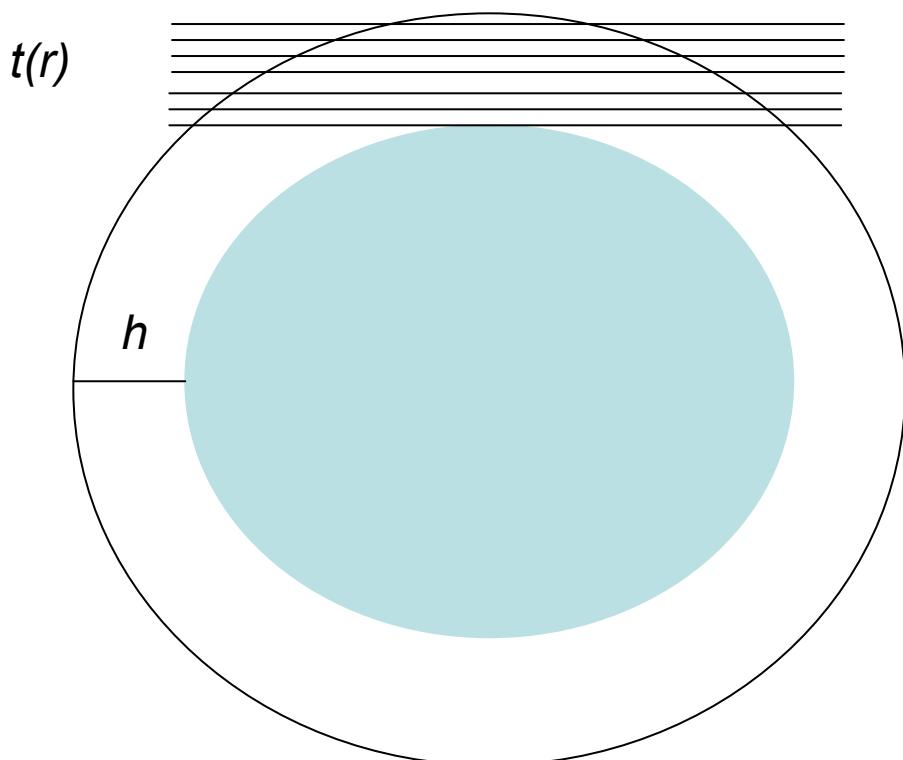
Is there a reference level that is most appropriate for radiation budget studies?

$$\frac{S_o}{4}(1 - \alpha) = F^a$$

$$\frac{S_o}{4}(1 - \alpha_h - t_h) = F_h^a$$



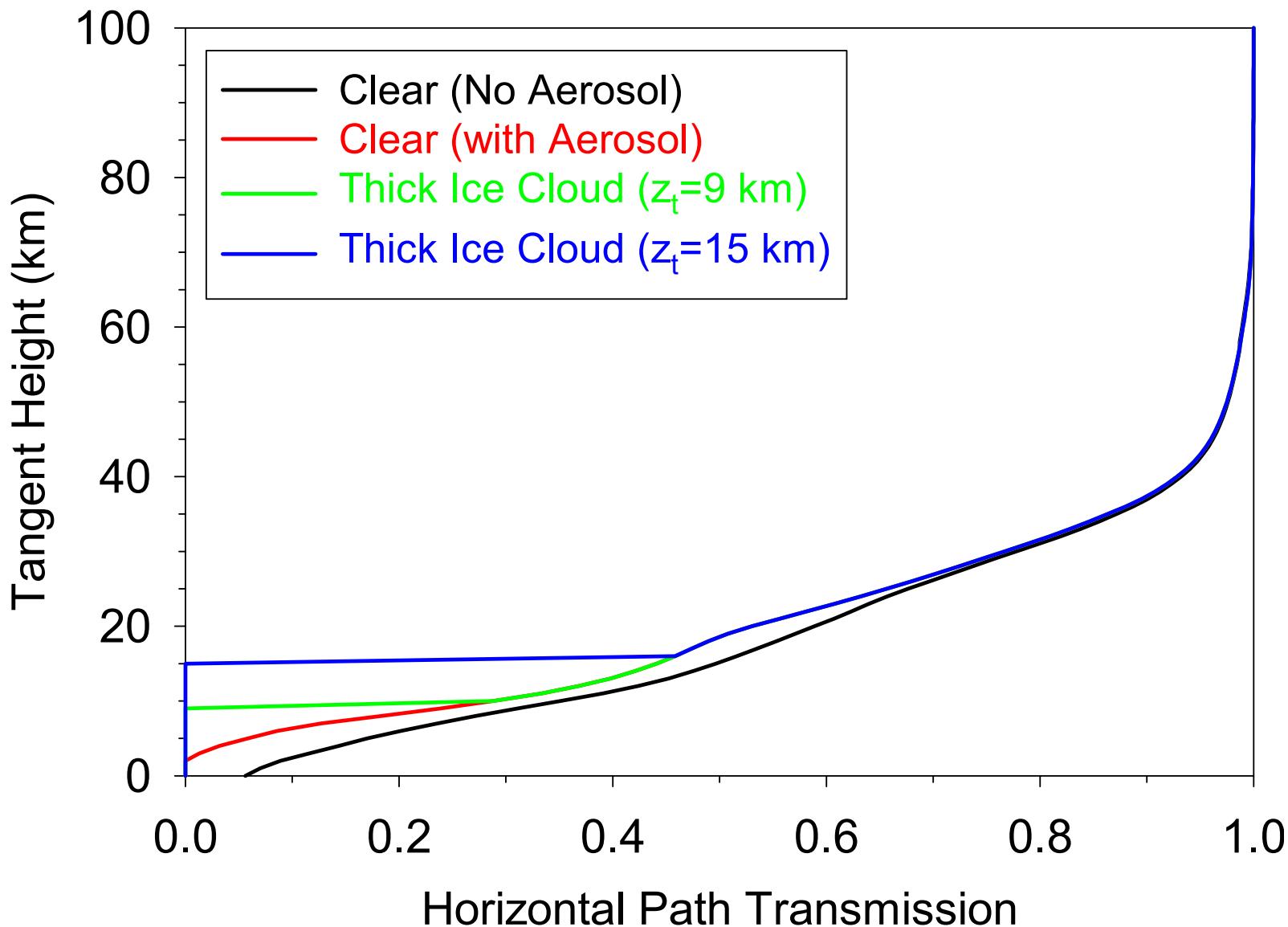
Effective Transmission t_h



$$t(r) = \frac{\int_0^{\infty} t_{\lambda}(r) S_{o\lambda} d\lambda}{\int_0^{\infty} S_{o\lambda} d\lambda}$$

$$t_h = \frac{\int_0^{r_e+h} 2\pi r t(r) dr}{\pi (r_e + h)^2}$$

MODTRAN Horizontal Path Transmission $t(r)$



t_h for Sample MODTRAN Cases (h=100 km)

Case	Profiles	Aerosol	Cloud	t_h (x10 ⁻²)
1	Tropical	No	No	2.503
2	Tropical	Yes	No	2.446
3	Tropical	Yes	Thick Ice; $z_t=9$ km	2.423
4	Tropical	Yes	Thick Ice; $z_t=15$ km	2.354
5	Subarctic Winter	No	No	2.546
6	No Atmosphere			3.067

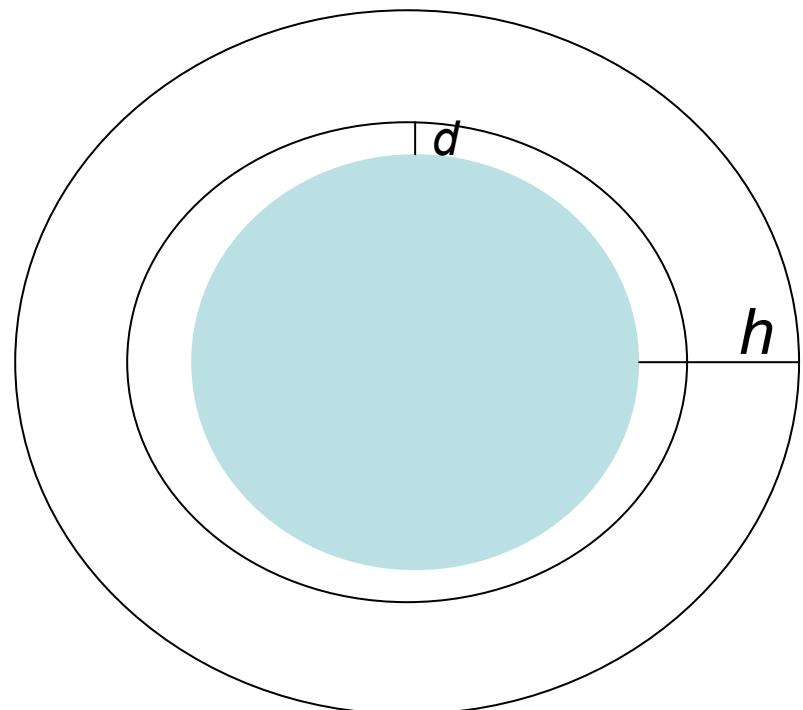
At an arbitrary reference level x :

$$\frac{S_o}{4} - \left(\frac{r_e + h}{r_e + x} \right)^2 (F_h^r + F_h^a) - t_x \frac{S_o}{4} = 0$$

$$t_x = 1 - \left(\frac{r_e + h}{r_e + x} \right)^2 (1 - t_h)$$

At $x=d$, $t_x=0$:

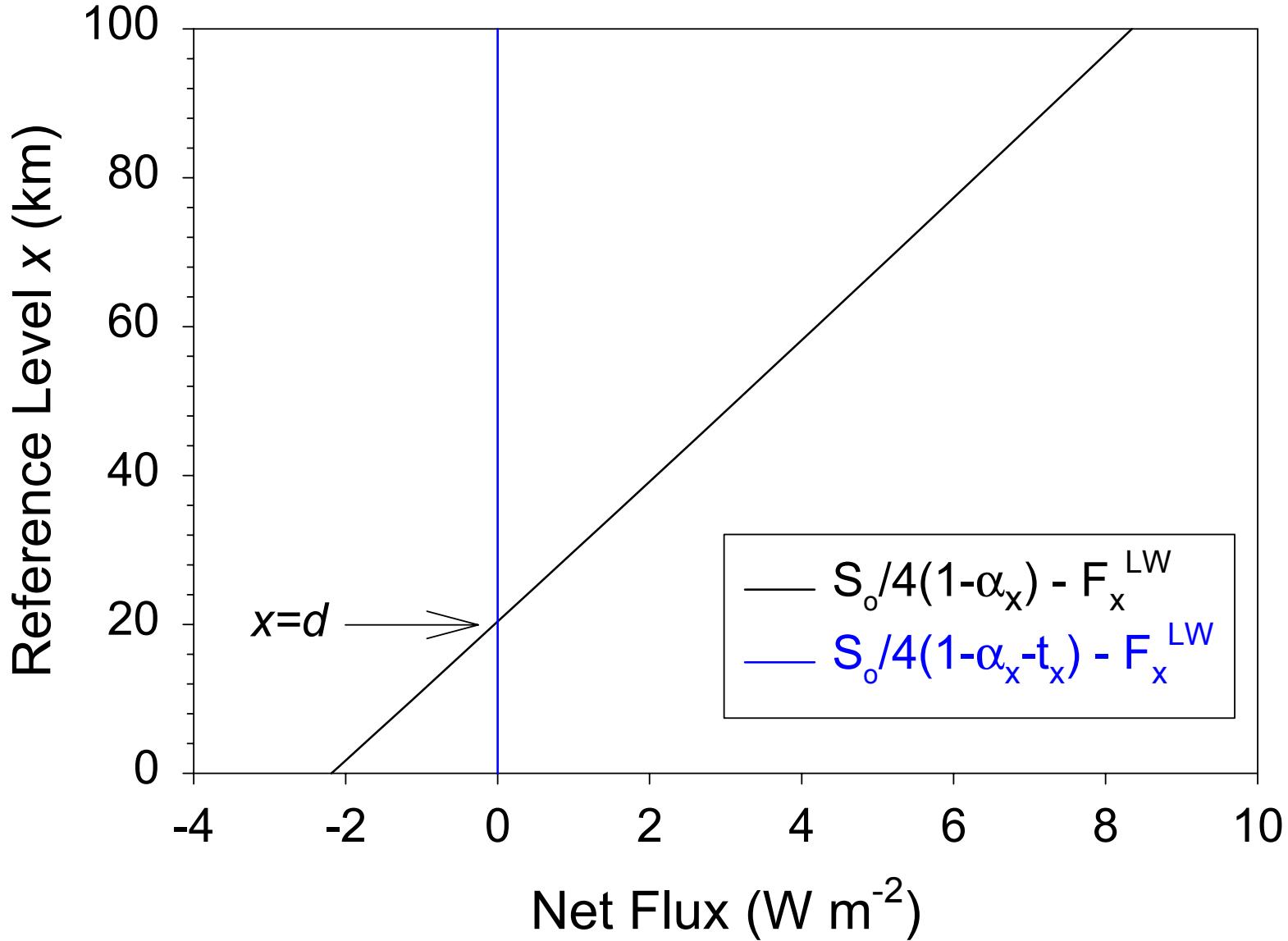
$$d = (r_e + h) \sqrt{1 - t_h} - r_e$$



t_h and d for Sample MODTRAN Cases (h=100 km)

Case	Profiles	Aerosol	Cloud	t_h (x10 ⁻²)	d (km)
1	Tropical	No	No	2.503	18.5
2	Tropical	Yes	No	2.446	20.5
3	Tropical	Yes	Thick Ice; $z_t=9$ km	2.423	21.1
4	Tropical	Yes	Thick Ice; $z_t=15$ km	2.354	23.4
5	Subarctic Winter	No	No	2.546	17.1
6	No Atmosphere			3.067	0

Net Flux vs Reference Level



Instantaneous TOA Flux Estimate

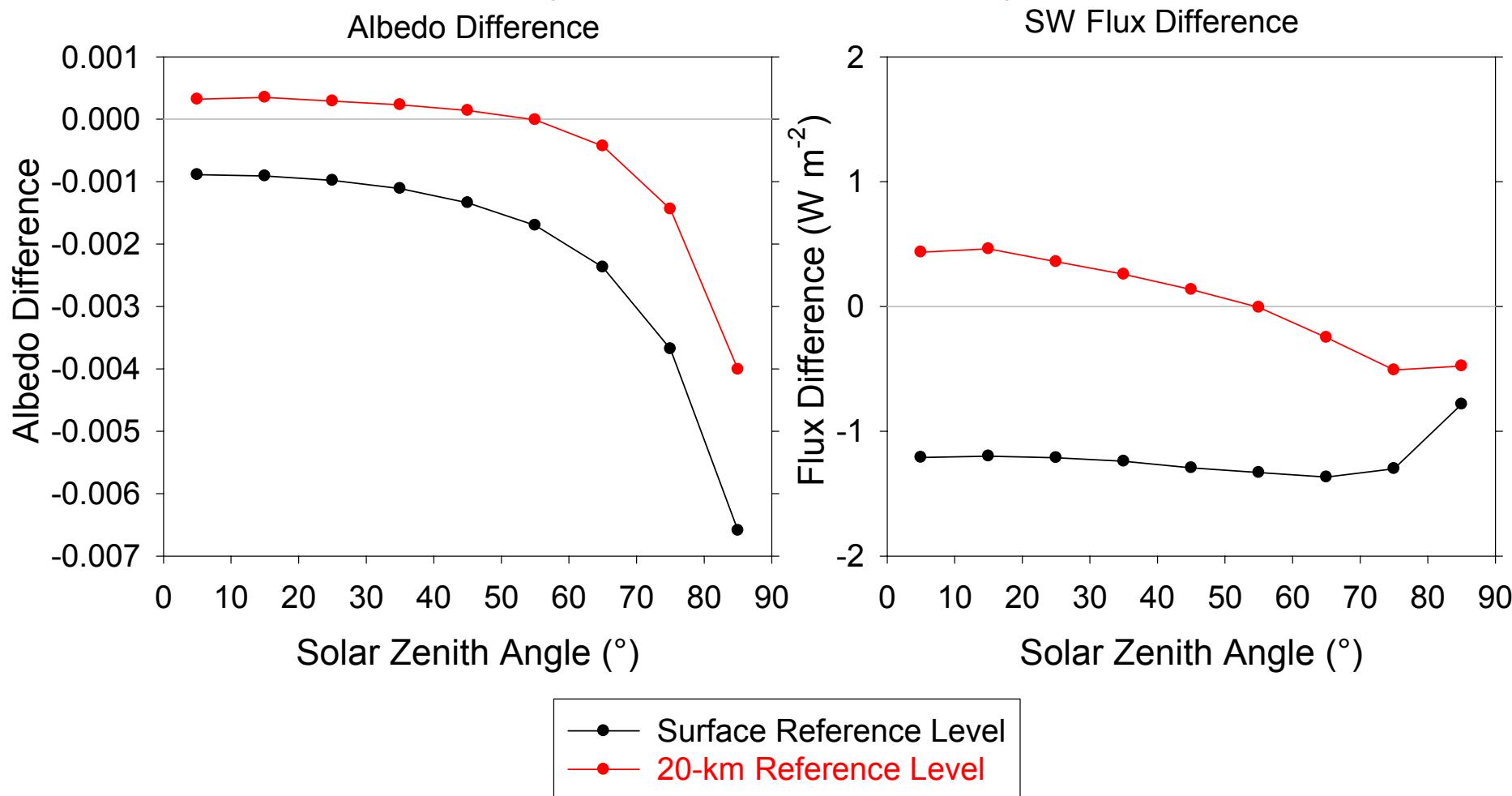
Instantaneous flux at 20-km reference level:

$$\hat{F}(\Omega; h_{20}) = \hat{F}(\Omega; h_{sfc}) \left(\frac{r_e}{r_e + h_{20}} \right)^2$$

where,

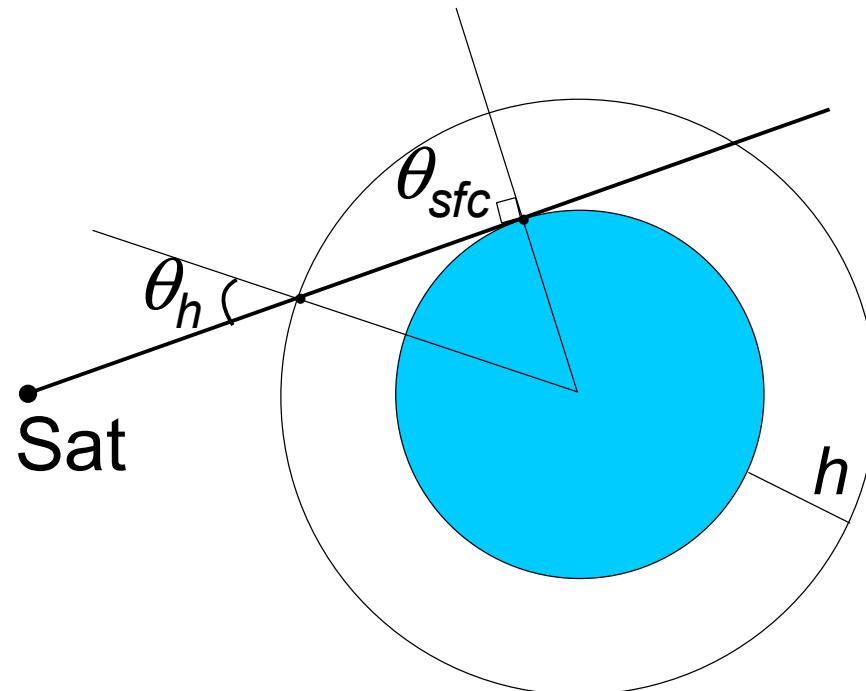
$$\hat{F}(\Omega; h_{sfc}) = \frac{\pi I(\Omega; h_{sfc})}{R_j(\Omega; h_{sfc})}$$

Tropical Average Albedo & SW Flux Difference (SSF Ed2A - SSF Ed2B)



Comparison with ERBE Methodology

- ERBE ADMs constructed from Nimbus-7 using a surface reference level.
 - On NOAA-9, 10 and ERBS, the ERBE ADMs were applied using viewing geometry defined at a 30-km reference level.
- ⇒ Viewing zenith used to estimate TOA flux is too small (inconsistent with how models were constructed).



Flux Error Due to Inconsistent Viewing Geometry

